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Montemerlo et al.

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(54) **ZONE DRIVING**

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(73) Assignee: **Google Inc.**, Mountain View, CA (US)

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Related U.S. Application Data

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G05D 1/02 (2006.01)
G05D 1/00 (2006.01)
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(52) **U.S. Cl.**
CPC ***G05D 1/0214*** (2013.01); ***B60W 30/08*** (2013.01); ***G05D 1/0055*** (2013.01); ***G05D 1/021*** (2013.01);
(Continued)

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CPC B60W 50/082; B60W 2050/0072; G05D 1/0061; G05D 1/021; G05D 1/0214; G05D 1/0274; G05D 1/0278
USPC 701/23, 25
See application file for complete search history.

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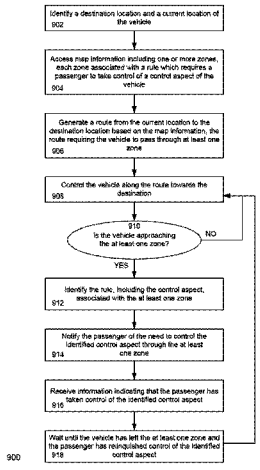
Assistant Examiner — David Testardi
(74) *Attorney, Agent, or Firm* — Lerner, David, Littenberg, Krumholz & Mentlik, LLP

(57) **ABSTRACT**

A roadgraph may include a graph network of information such as roads, lanes, intersections, and the connections between these features. The roadgraph may also include one or more zones associated with particular rules. The zones may include locations where driving is typically challenging such as merges, construction zones, or other obstacles. In one example, the rules may require an autonomous vehicle to alert a driver that the vehicle is approaching a zone. The vehicle may thus require a driver to take control of steering, acceleration, deceleration, etc. In another example, the zones may be designated by a driver and may be broadcast to other nearby vehicles, for example using a radio link or other network such that other vehicles may be able to observer the same rule at the same location or at least notify the other vehicle's drivers that another driver felt the location was unsafe for autonomous driving.

20 Claims, 12 Drawing Sheets



(51) **Int. Cl.**

B60W 30/08	(2012.01)
B60W 30/186	(2012.01)
B60W 50/029	(2012.01)
G06K 9/00	(2006.01)
G06K 9/32	(2006.01)

(52) **U.S. Cl.**

CPC *B60W 30/186* (2013.01); *B60W 2050/0292* (2013.01); *B60W 2530/14* (2013.01); *B60W 2550/22* (2013.01); *G05D 1/024* (2013.01); *G05D 1/0246* (2013.01); *G05D 1/0257* (2013.01); *G05D 1/0274* (2013.01); *G05D 1/0278* (2013.01); *G05D 2201/0213* (2013.01); *G06K 9/00791* (2013.01); *G06K 9/00798* (2013.01); *G06K 9/00805* (2013.01); *G06K 9/3241* (2013.01)

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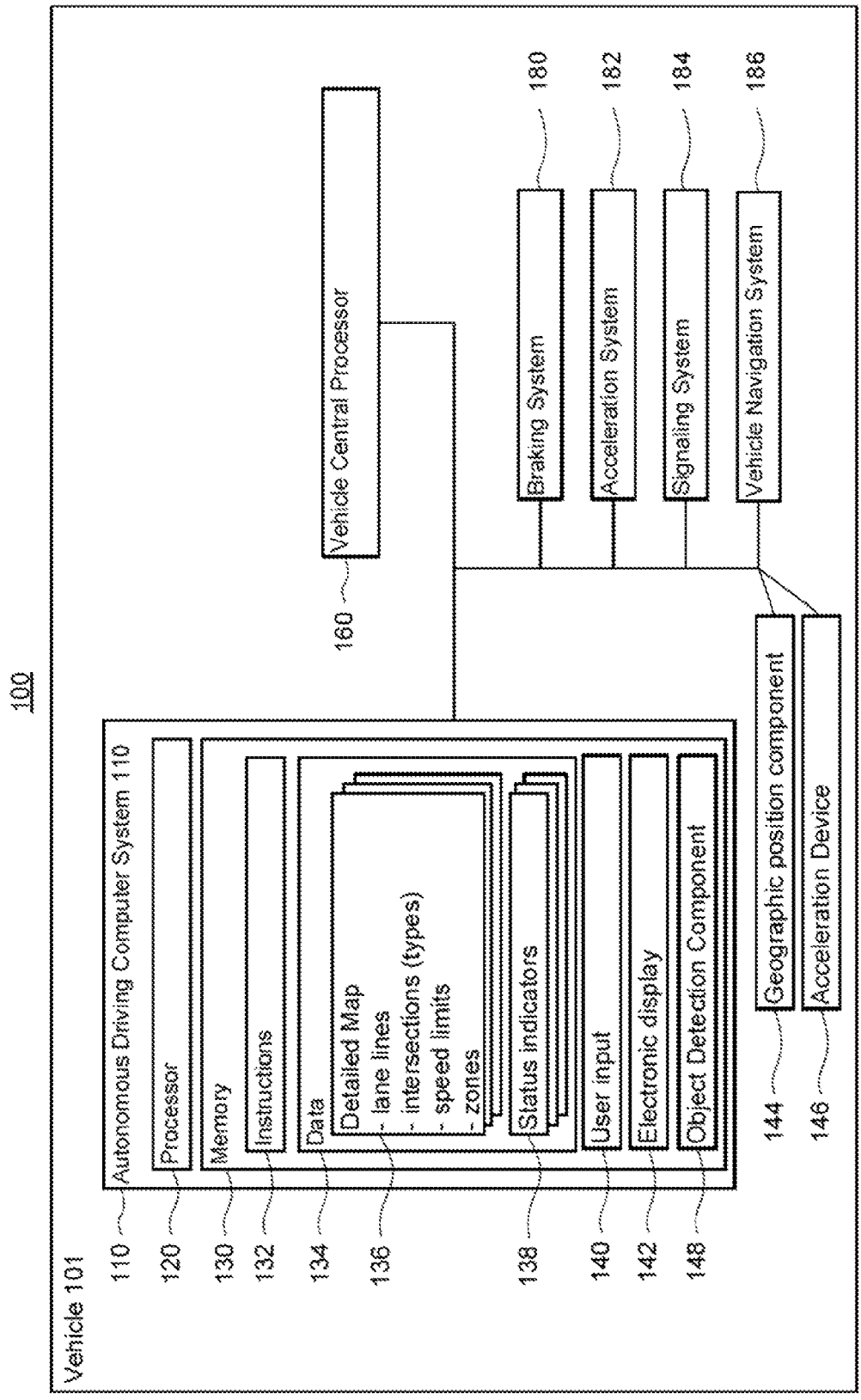
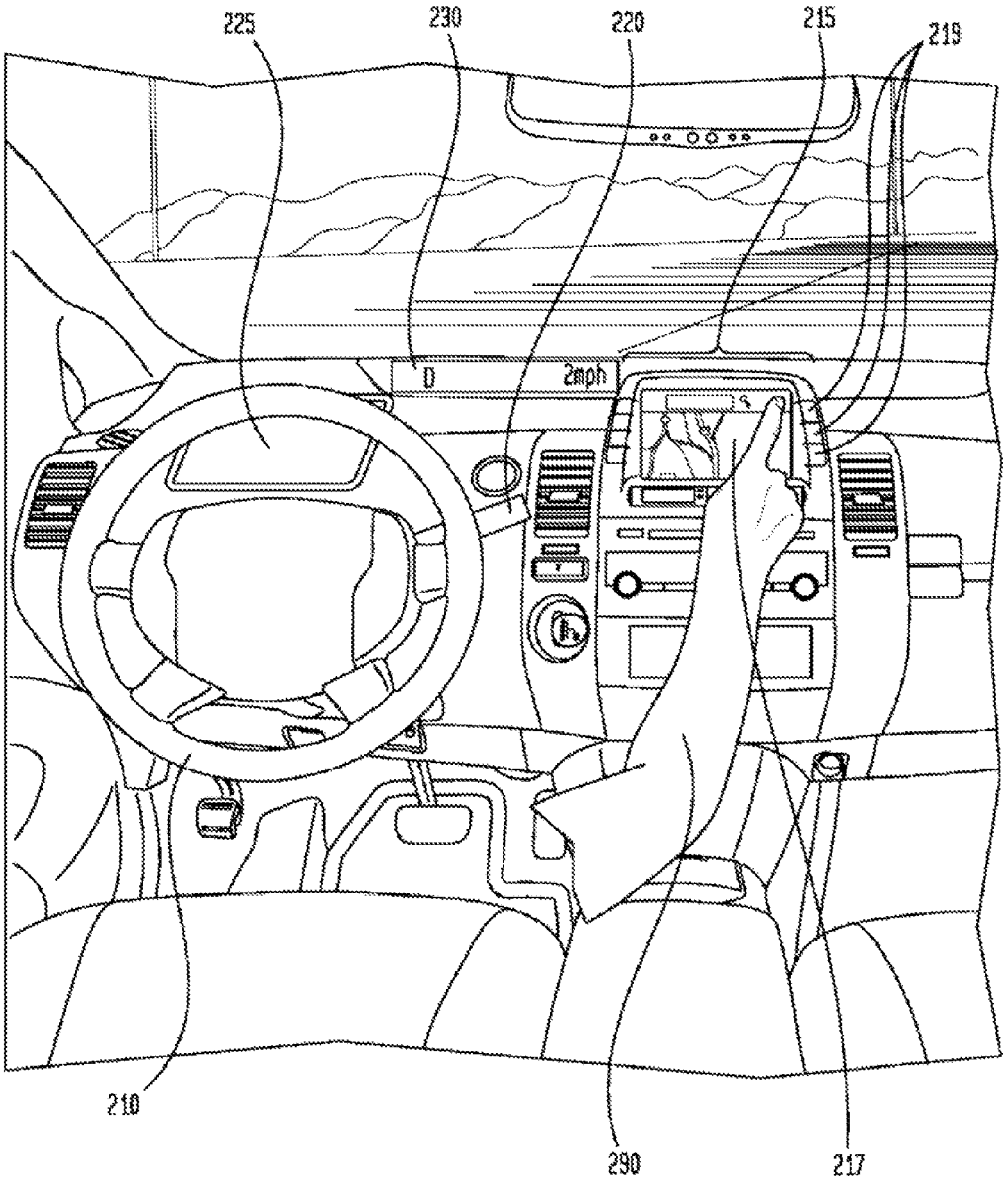

100
Vehicle 101
Autonomous Driving Computer System 110
Processor
Memory
Instructions
Data
Detailed Map
- lane lines
- intersections (types)
- speed limits
- zones
Status indicators
User input
Electronic display
Object Detection Component
110
120
130
132
134
136
138
140
142
148
Vehicle Central Processor
160
Braking System
Acceleration System
Signaling System
Vehicle Navigation System
180
182
184
186
Geographic position component
Acceleration Device
144
146

FIGURE 1

FIGURE 2



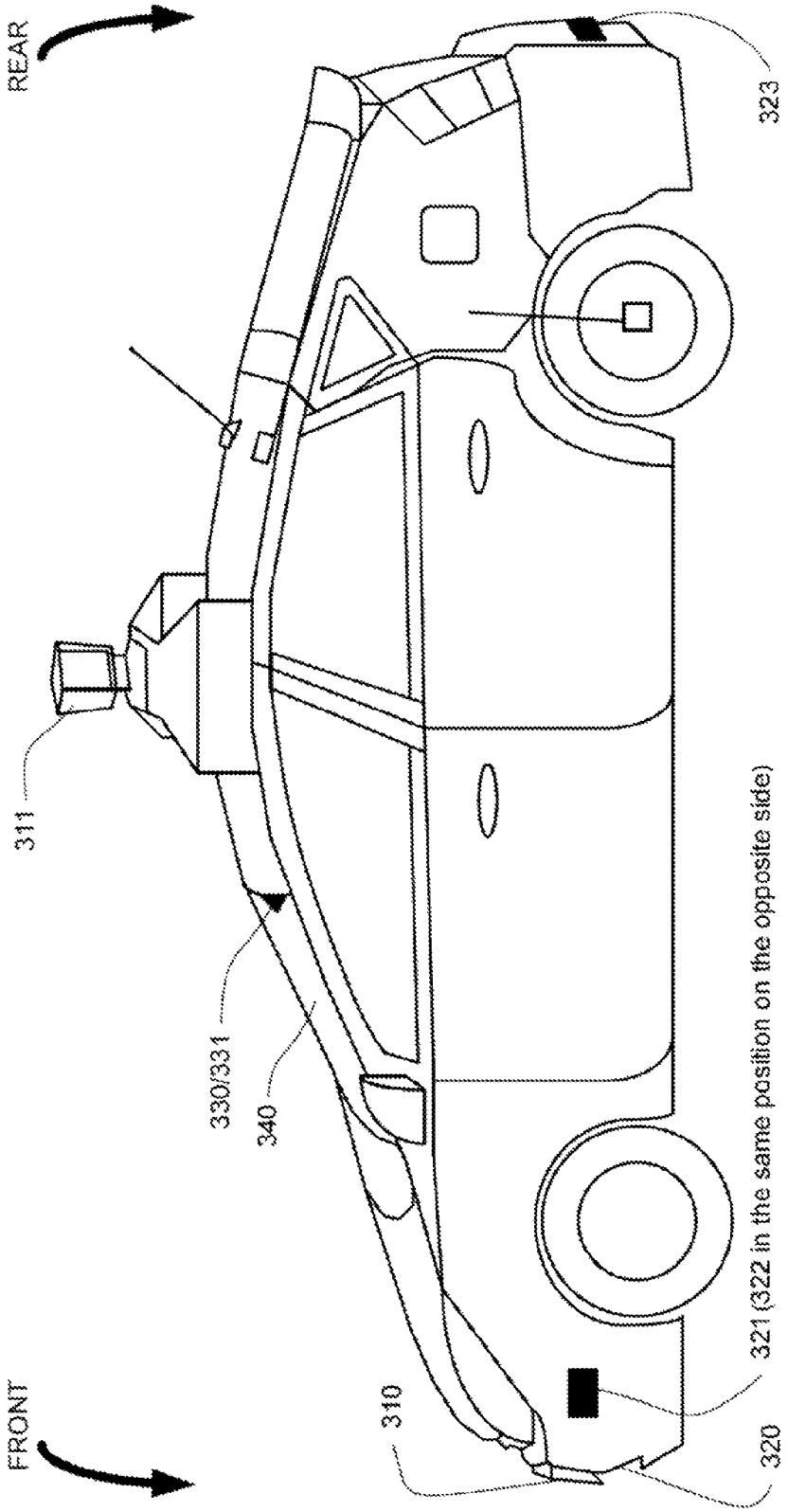

REAR
FRONT
311
330/331
340
310
320
321 (322 in the same position on the opposite side)
323
300

FIGURE 3

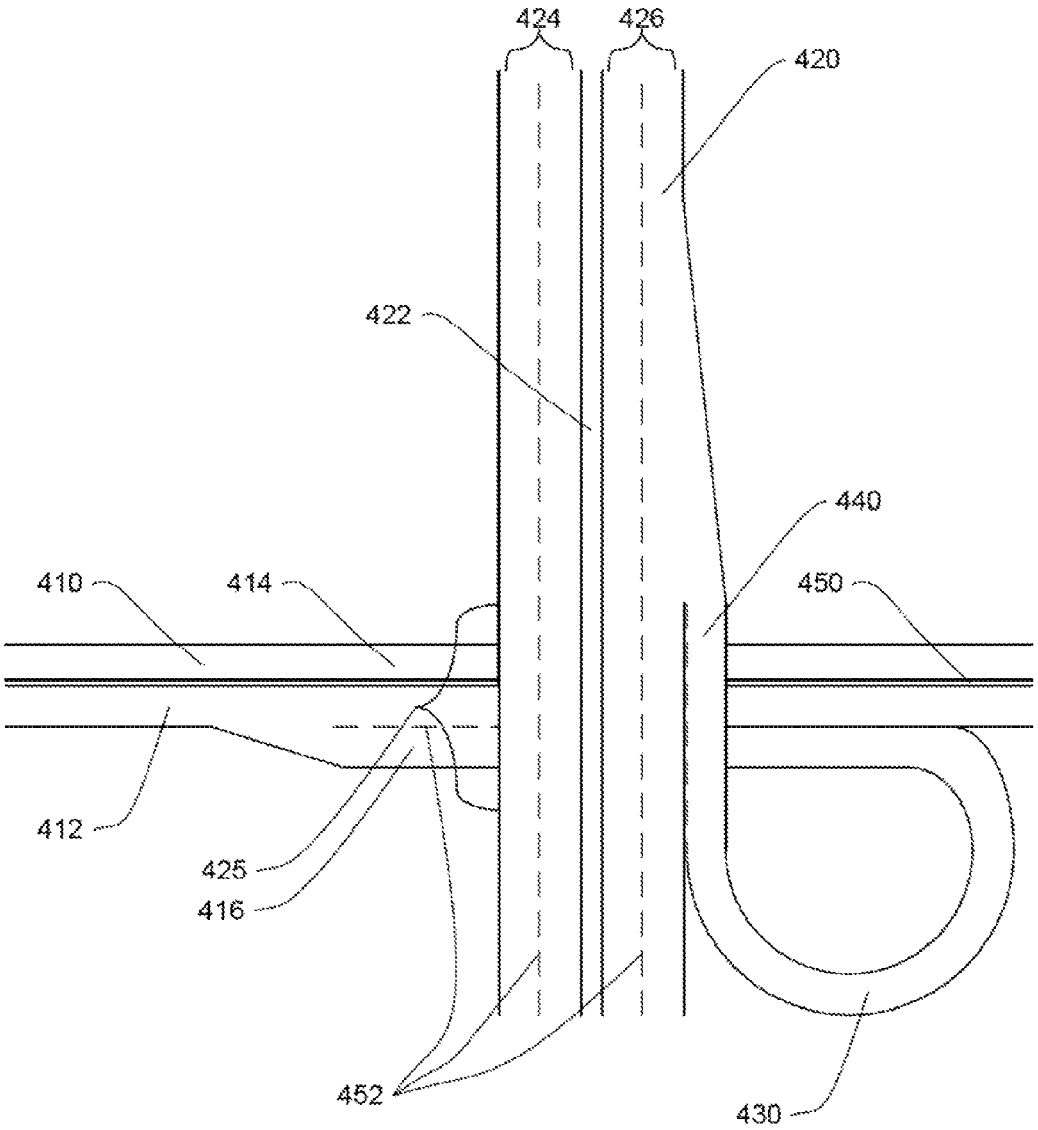


FIGURE 4

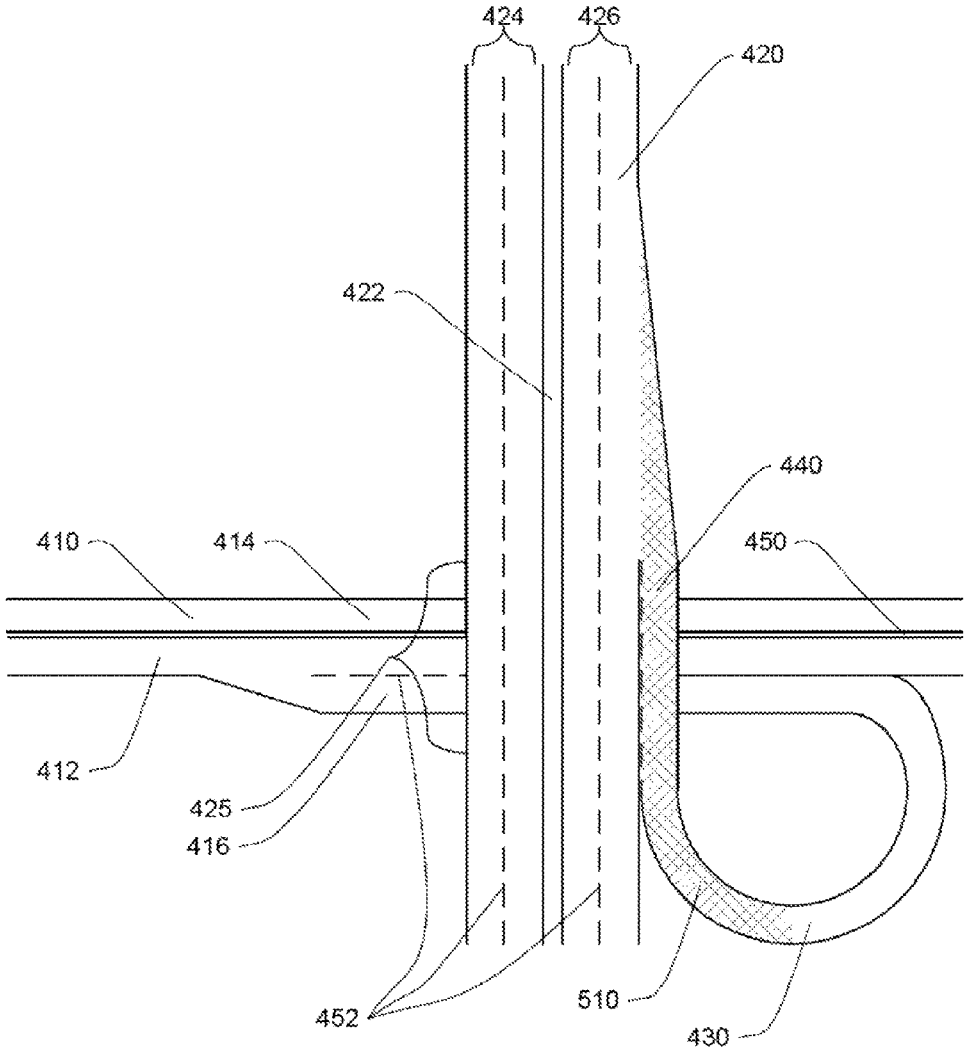


FIGURE 5

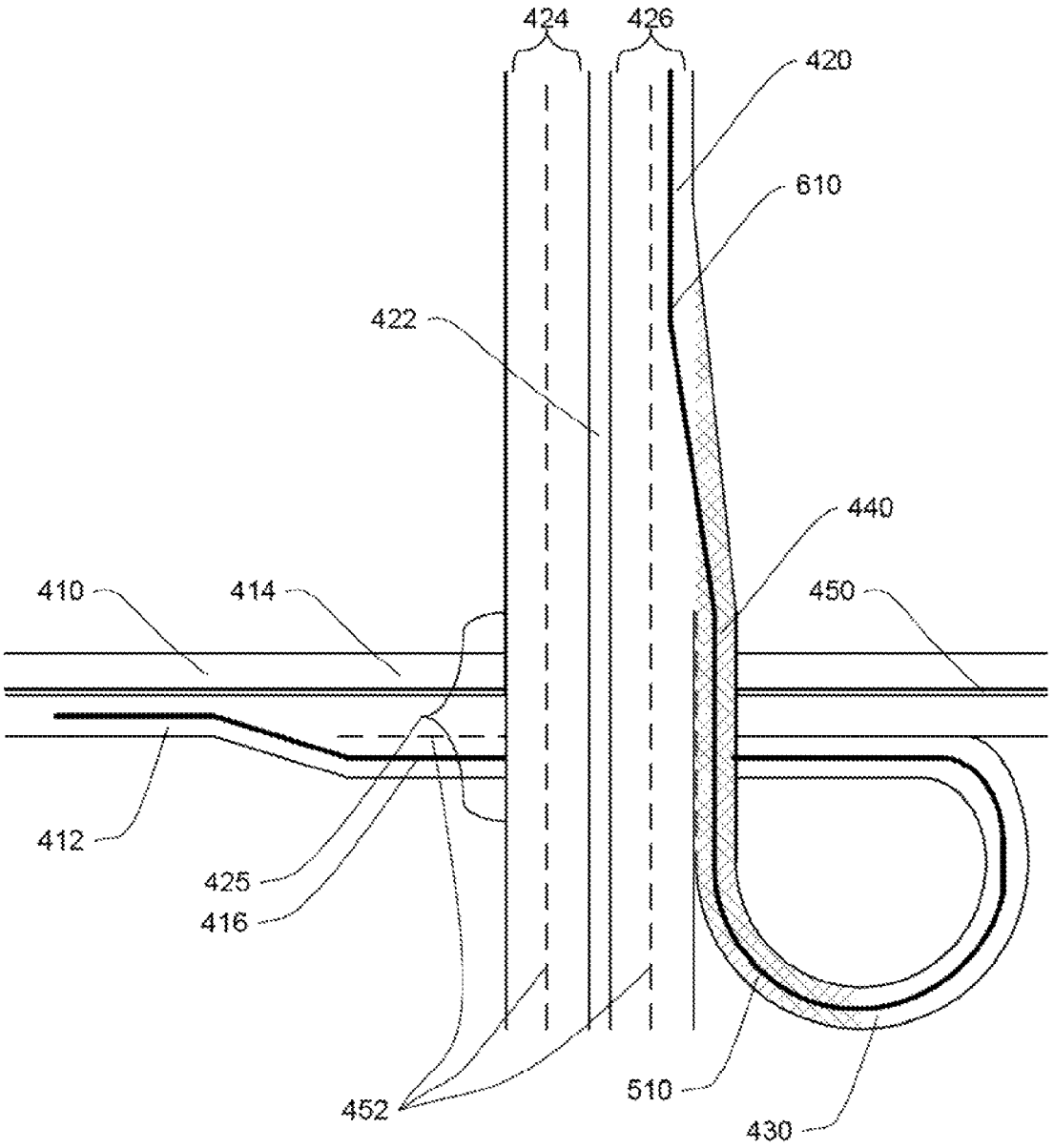
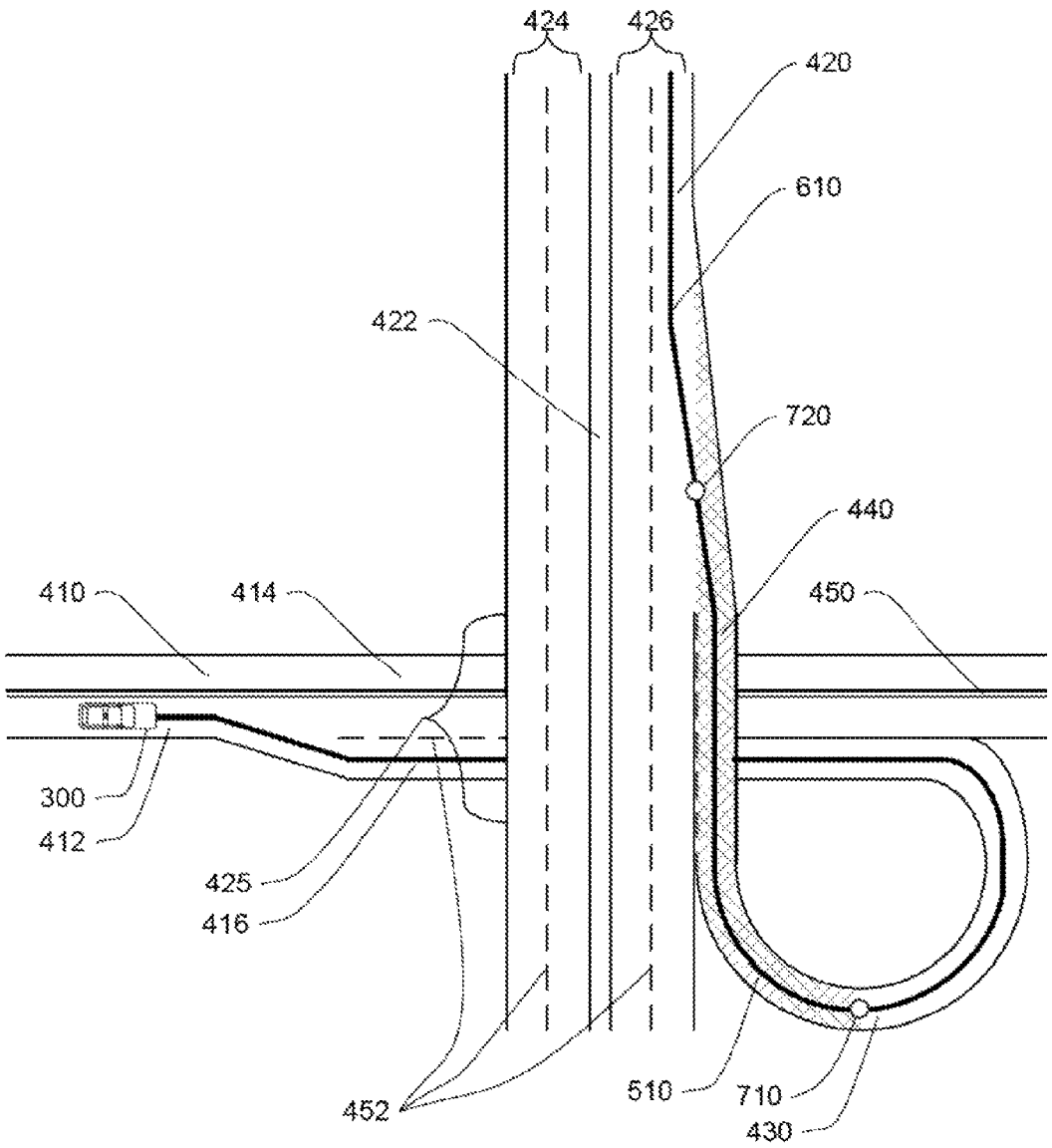
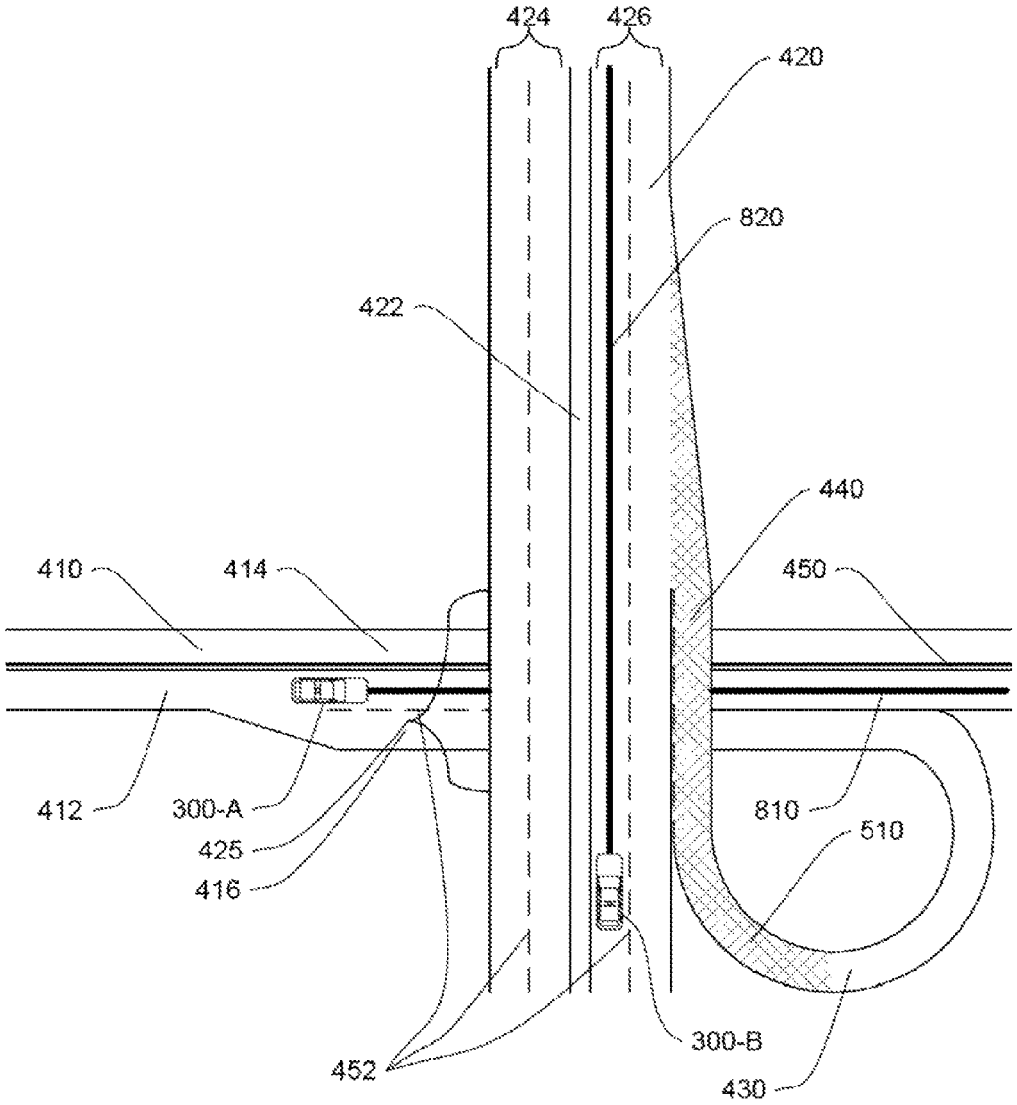


FIGURE 6


424
426
420
610
422
720
440
410
414
450
300
412
425
416
452
510
710
430

700

FIGURE 7


424
426
420
820
422
440
410
414
450
412
300-A
425
416
810
510
452
300-B
430

800

FIGURE 8

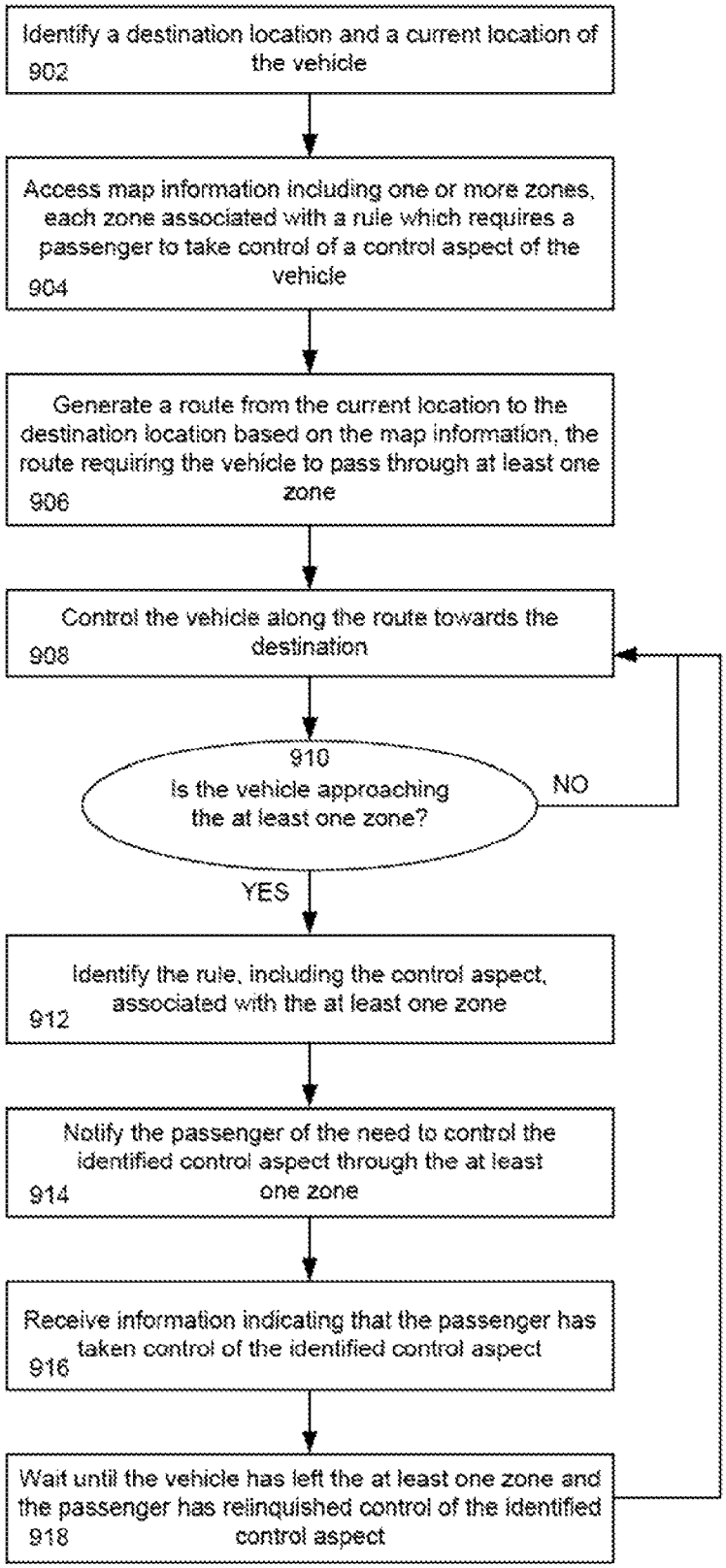

Identify a destination location and a current location of the vehicle
902
Access map information including one or more zones, each zone associated with a rule which requires a passenger to take control of a control aspect of the vehicle
904
Generate a route from the current location to the destination location based on the map information, the route requiring the vehicle to pass through at least one zone
906
Control the vehicle along the route towards the destination
908
910
Is the vehicle approaching the at least one zone?
NO
YES
Identify the rule, including the control aspect, associated with the at least one zone
912
Notify the passenger of the need to control the identified control aspect through the at least one zone
914
Receive information indicating that the passenger has taken control of the identified control aspect
916
Wait until the vehicle has left the at least one zone and the passenger has relinquished control of the identified control aspect
918
900

FIGURE 9A

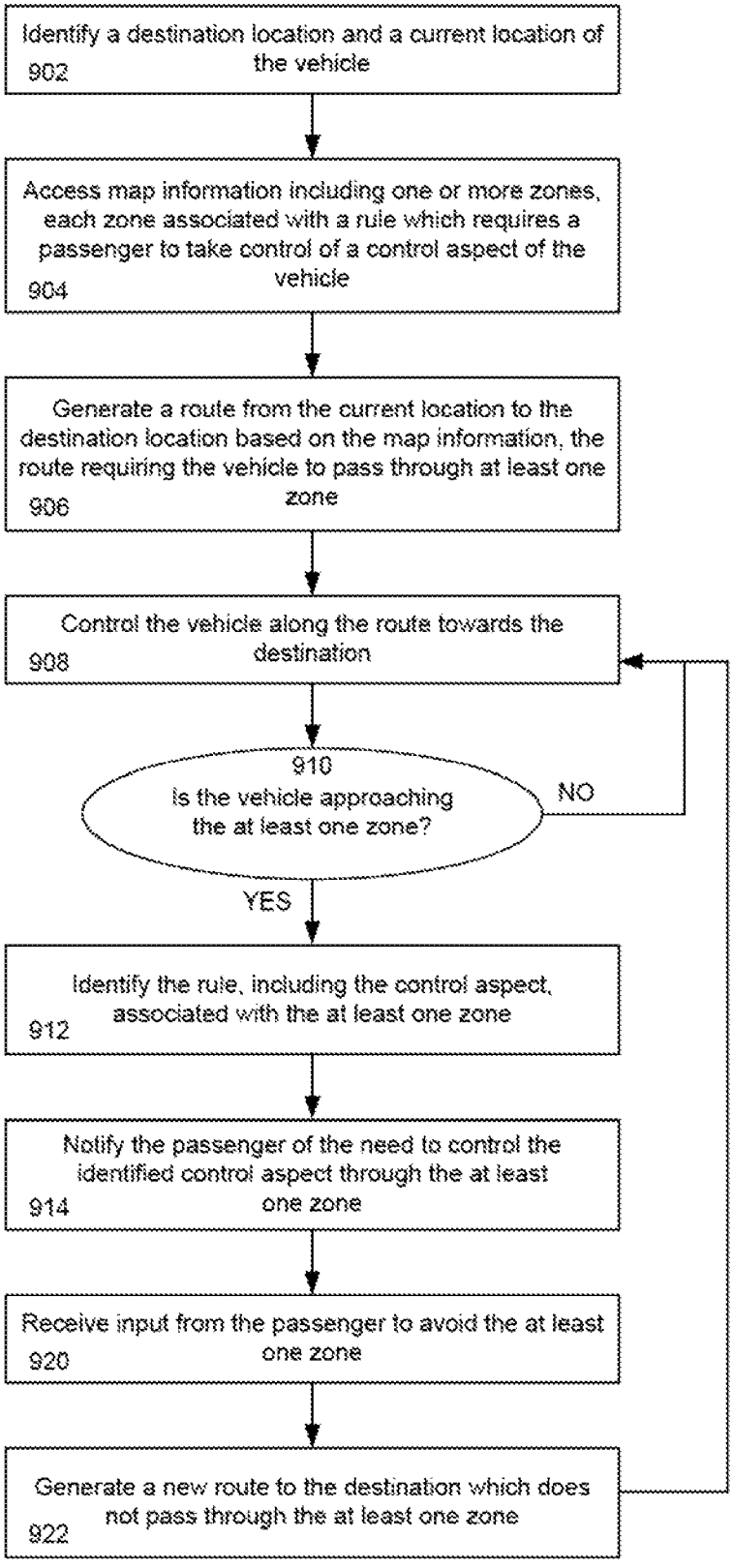

Identify a destination location and a current location of the vehicle
902
Access map information including one or more zones, each zone associated with a rule which requires a passenger to take control of a control aspect of the vehicle
904
Generate a route from the current location to the destination location based on the map information, the route requiring the vehicle to pass through at least one zone
906
Control the vehicle along the route towards the destination
908
910
Is the vehicle approaching the at least one zone?
NO
YES
Identify the rule, including the control aspect, associated with the at least one zone
912
Notify the passenger of the need to control the identified control aspect through the at least one zone
914
Receive input from the passenger to avoid the at least one zone
920
Generate a new route to the destination which does not pass through the at least one zone
922
900

FIGURE 9B

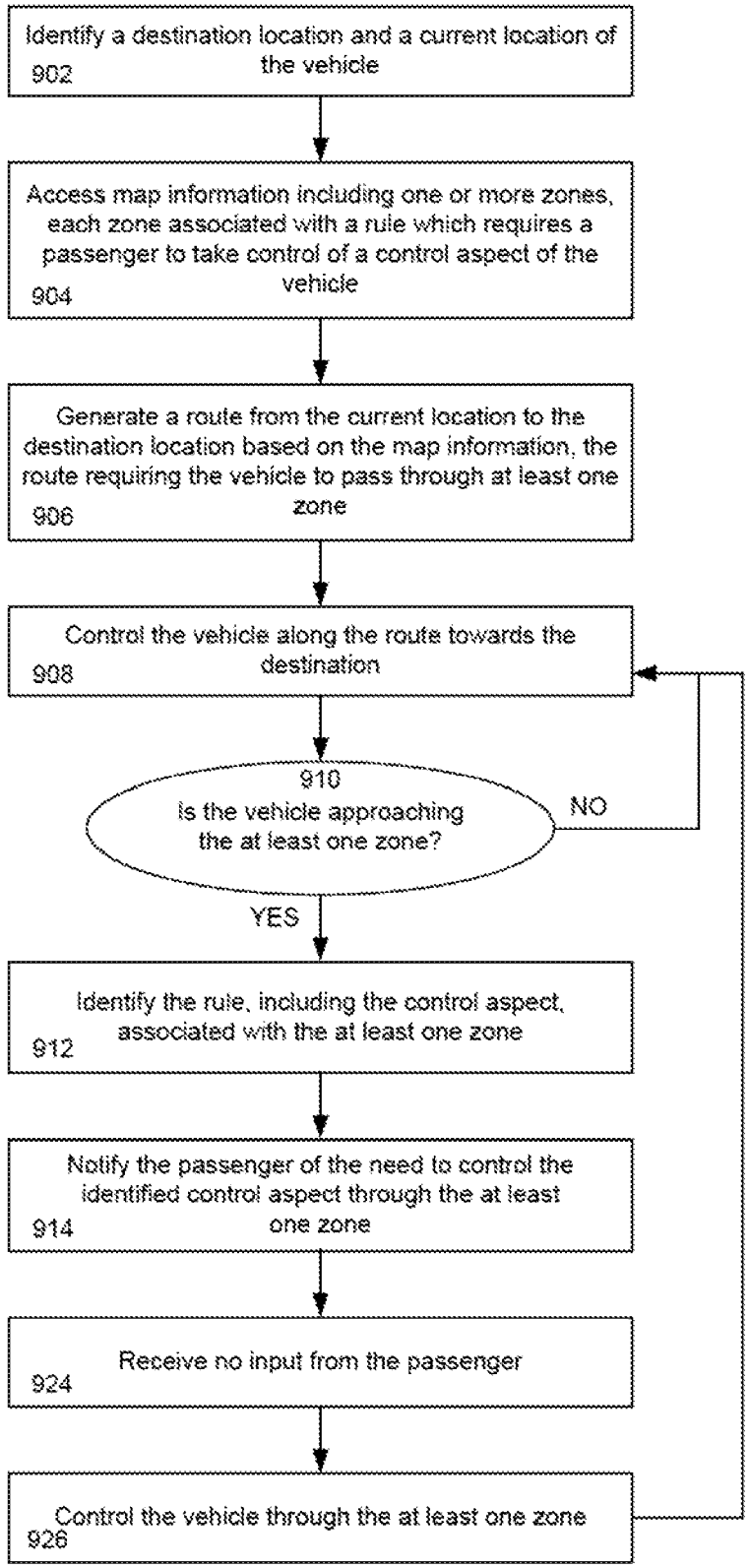

Identify a destination location and a current location of the vehicle
902
Access map information including one or more zones, each zone associated with a rule which requires a passenger to take control of a control aspect of the vehicle
904
Generate a route from the current location to the destination location based on the map information, the route requiring the vehicle to pass through at least one zone
906
Control the vehicle along the route towards the destination
908
910
Is the vehicle approaching the at least one zone?
NO
YES
Identify the rule, including the control aspect, associated with the at least one zone
912
Notify the passenger of the need to control the identified control aspect through the at least one zone
914
Receive no input from the passenger
924
Control the vehicle through the at least one zone
926
900

FIGURE 9C

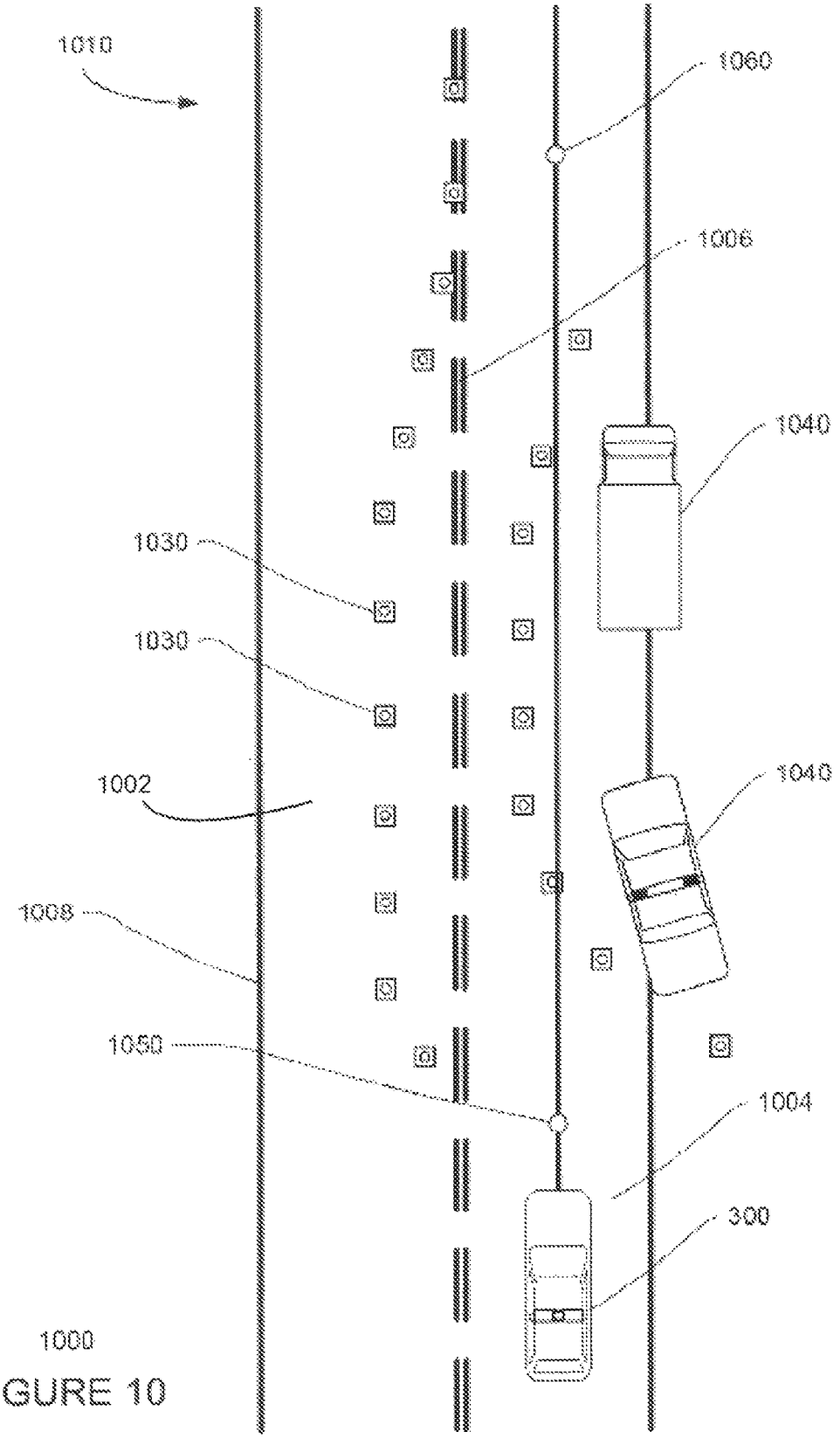

1010
1060
1006
1040
1030
1030
1002
1040
1008
1050
1004
300
1000

FIGURE 10

ZONE DRIVING

CROSS-REFERENCE TO RELATED APPLICATION

The present application is a continuation of U.S. patent application Ser. No. 13/932,090, entitled "ZONE DRIVING," filed Jul. 1, 2013, which is a continuation of U.S. patent application Ser. No. 13/150,589, entitled "ZONE DRIVING," filed Jun. 1, 2011, which claims the benefit of U.S. Provisional Application No. 61/390,094, entitled "AUTONOMOUS VEHICLES," filed Oct. 5, 2010, and U.S. Provisional Application No. 61/391,271, entitled "AUTONOMOUS VEHICLES," filed Oct. 8, 2010, the entire disclosures of which are hereby incorporated herein by reference.

BACKGROUND

Autonomous vehicles use various computing systems to aid in the transport of drivers from one location to another. Some autonomous vehicles may require some initial input or continuous input from an operator, such as a pilot or driver. Other systems, for example autopilot systems, may be used only when the system has been engaged, which permits the operator to switch from a manual mode (where the operator exercises a high degree of control over the movement of the vehicle) to an autonomous mode (where the vehicle essentially drives itself) to modes that lie somewhere in between.

These autonomous vehicles may maneuver themselves between locations based using highly detailed maps in conjunction with sensors for detecting objects in the vehicle's surroundings in order to maneuver the vehicle from one location to another. This may require the vehicle to navigate through areas where the driver may not feel particularly safe allowing the vehicle to maneuver itself. For example, a driver may feel less safe in areas such as merges, traffic circles, complicated intersections, etc. which may be considered more complicated for an autonomous vehicle to maneuver through. Thus, the driver may feel the need to continuously monitor the vehicle's location in case the driver must take control of the vehicle. This may lessen the usefulness of an autonomous vehicle and the driver's sense of safety.

BRIEF SUMMARY

One aspect of the disclosure provides a method for maneuvering a vehicle. The method includes accessing map information including one or more zones, each zone being associated with a rule that indicates a driver to take control of a control aspect of the vehicle; identifying, by a processor, a route based on the map information, where the route requires the vehicle to pass through at least one zone of the one or more zones; maneuvering, by the processor, the vehicle to the destination; and when the vehicle is within a predetermined distance along the route of the at least one zone, identifying the rule associated with the at least one zone, identifying the control aspect of the identified rule, and notifying the driver of the need to control the identified control aspect through the at least one zone.

In one example, the identified control aspect includes at least one of steering, acceleration, and braking. In another example, the method also includes receiving information indicating that the driver has taken control of the identified control aspect; waiting until the vehicle has left the at least one zone and the driver has relinquished control of the identified control aspect; and continuing to maneuver the vehicle along the route towards the destination. In another example, the method also includes receiving input identifying a destination location and identifying the route is further based on the destination location. The method may also include receiving instructions from the driver to avoid the at least one zone; generating a new route to the destination which does not pass through the at least one zone; and maneuvering the vehicle along the new route. In another example, the method also includes, when the driver has not taken control of the identified control aspect and once the vehicle reaches the at least one zone, maneuvering the vehicle through the at least one zone along the route. In another example, the method also includes identifying a first location based on the driver controlling a given control aspect of the vehicle; identifying a second location based on the driver relinquishing control of the given control aspect of the control vehicle; generating a new zone based on the first location and the second location; generating a new rule for the new zone based on the given control aspect; and storing the new zone and the new rule with the map information. The method may also include transmitting the new zone and the new rule to another vehicle.

Another aspect of the invention provides a tangible, non-transitory, computer-readable storage medium on which computer readable instructions of a program are stored. The instructions, when executed by a processor, cause the processor to perform a method of maneuvering a vehicle. The method includes accessing map information including one or more zones, each zone being associated with a rule that indicates a driver to take control of a control aspect of the vehicle; identifying, by a processor, a route based on the map information, where the route requires the vehicle to pass through at least one zone of the one or more zones; maneuvering, by the processor, the vehicle to the destination; and when the vehicle is within a predetermined distance along the route of the at least one zone, identifying the rule associated with the at least one zone, identifying the control aspect of the identified rule, and notifying the driver of the need to control the identified control aspect through the at least one zone.

In one example, the identified control aspect includes at least one of steering, acceleration, and braking. In another example, the method also includes receiving information indicating that the driver has taken control of the identified control aspect; waiting until the vehicle has left the at least one zone and the driver has relinquished control of the identified control aspect; and continuing to maneuver the vehicle along the route towards the destination. In another example, the method also includes receiving input identifying a destination location and identifying the route is further based on the destination location. The method may also include receiving instructions from the driver to avoid the at least one zone; generating a new route to the destination which does not pass through the at least one zone; and maneuvering the vehicle along the new route. In another example, the method also includes, when the driver has not taken control of the identified control aspect and once the vehicle reaches the at least one zone, maneuvering the vehicle through the at least one zone along the route. In another example, the method also includes identifying a first location based on the driver controlling a given control aspect of the vehicle; identifying a second location based on the driver relinquishing control of the given control aspect of the control vehicle; generating a new zone based on the first location and the second location; generating a new rule for the new zone based on the given control aspect; and storing the new zone and the new rule with the map information. The method may also include transmitting the new zone and the new rule to another vehicle.

Yet another aspect of the disclosure provides a vehicle. The vehicle includes a plurality of control aspects for controlling movement of the vehicle; memory storing map information including one or more zones, each zone being associated with a rule that indicates a driver to take control of at least one control aspect of the plurality of control aspects; and a processor coupled to the plurality of control aspects and the memory. The processor is operable to identify a route based on the map information, where the route requires the vehicle to pass through at least one zone of the one or more zones; maneuver the vehicle along the route; and when the vehicle is within a predetermined distance along the route of the at least one zone, identify the rule associated with the at least one zone, identify the control aspect of the identify rule, and notify a driver of the need to control the identified control aspect through the at least one zone.

In one example, the processor is further operable to, when the driver has not taken control of the identified control aspect and once the vehicle reaches the at least one zone, maneuver the vehicle through the at least one zone along the route. In another example, the processor is also operable to identify a first location based on the driver controlling a given control aspect of the vehicle; identify a second location based on the driver relinquishing control of the given control aspect of the vehicle; generate a new zone based on the first location and the second location; generate a new rule for the new zone based on the given control aspect; and store the new zone and the new rule with the map information. The processor may also be operable to operable to transmit the new zone and the new rule to another autonomous vehicle. In another example, the identified control aspect includes at least one of a steering system, an acceleration system, and a braking system.

Still a further aspect of the disclosure provides a method of maneuvering a vehicle. The method includes maneuvering, by a processor, the vehicle along a current path on a roadway; determining whether the vehicle is within a distance along the current path of at least one zone associated with a rule that requires a driver to take control of at least one control aspect of the vehicle; and when the vehicle is within the distance along the current path of the at least one zone, notifying the driver of the need to control the at least one control aspect through the at least one zone.

In one example, the at least one control aspect includes at least one of steering, acceleration, and braking. In another example, the method also includes receiving information indicating that the driver has taken control of the identified control aspect; waiting until the vehicle has left the at least one zone and the driver has relinquished control of the identified control aspect; and continuing to maneuver the vehicle by the processor. In another example, the method also includes, when the driver has not taken control of the at least one control aspect and once the vehicle reaches the at least one zone, maneuvering the vehicle through the at least one zone. In another example, the method also includes identifying a first location based on the driver controlling a given control aspect of the vehicle; identifying a second location based on the driver relinquishing control of the given control aspect of the vehicle; generating a new zone based on the first location and the second location; generating a new rule for the new zone based on the given control aspect; and storing the new zone and the new rule with the map information. The method may also include transmitting the new zone and the new rule to another vehicle.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a functional diagram of a system in accordance with an exemplary embodiment.

FIG. **2** is an interior of an autonomous vehicle in accordance with an exemplary embodiment.

FIG. **3** is an exterior of an autonomous vehicle in accordance with an exemplary embodiment

FIG. **4** is a road map in accordance with an exemplary embodiment.

FIG. **5** is another road map in accordance with an exemplary embodiment.

FIG. **6** is another road map in accordance with an exemplary embodiment.

FIG. **7** is another road map in accordance with an exemplary embodiment.

FIG. **8** is another road map in accordance with an exemplary embodiment.

FIGS. **9A-9C** are flow diagrams in accordance with exemplary embodiments.

FIG. **10** is another exemplary road map in accordance with an exemplary embodiment.

DETAILED DESCRIPTION

As shown in FIG. **1**, an autonomous driving system **100** in accordance with one aspect of the disclosure includes a vehicle **101** with various components. While certain aspects of the disclosure are particularly useful in connection with specific types of vehicles, the vehicle **101** may be any type of vehicle including, but not limited to, cars, trucks, motorcycles, busses, boats, airplanes, helicopters, lawnmowers, recreational vehicles, amusement park vehicles, farm equipment, construction equipment, trams, golf carts, trains, and trolleys. The vehicle may have one or more computers, such as computer **110** containing a processor **120**, memory **130** and other components typically present in general purpose computers.

The memory **130** stores information accessible by processor **120**, including instructions **132** and data **134** that may be executed or otherwise used by the processor **120**. The memory **130** may be of any type capable of storing information accessible by the processor, including a computer-readable medium, or other medium that stores data that may be read with the aid of an electronic device, such as a hard-drive, memory card, ROM, RAM, DVD or other optical disks, as well as other write-capable and read-only memories. Systems and methods may include different combinations of the foregoing, whereby different portions of the instructions and data are stored on different types of media.

The instructions **132** may be any set of instructions to be executed directly (such as machine code) or indirectly (such as scripts) by the processor. For example, the instructions may be stored as computer code on the computer-readable medium. In that regard, the terms "instructions" and "programs" may be used interchangeably herein. The instructions may be stored in object code format for direct processing by the processor, or in any other computer language including scripts or collections of independent source code modules that are interpreted on demand or compiled in advance. Functions, methods and routines of the instructions are explained in more detail below.

The data **134** may be retrieved, stored or modified by processor **120** in accordance with the instructions **132**. For instance, although the claimed subject matter is not limited by any particular data structure, the data may be stored in computer registers, in a relational database as a table having a

plurality of different fields and records, XML documents or flat files. The data may also be formatted in any computer-readable format. By further way of example only, image data may be stored as bitmaps comprised of grids of pixels that are stored in accordance with formats that are compressed or uncompressed, lossless (e.g., BMP) or lossy (e.g., JPEG), and bitmap or vector-based (e.g., SVG), as well as computer instructions for drawing graphics. The data may comprise any information sufficient to identify the relevant information, such as numbers, descriptive text, proprietary codes, references to data stored in other areas of the same memory or different memories (including other network locations) or information that is used by a function to calculate the relevant data.

The processor **120** may be any conventional processor, such as commercially available CPUs. Alternatively, the processor may be a dedicated device such as an ASIC or other hardware-based processor. Although FIG. **1** functionally illustrates the processor, memory, and other elements of computer **110** as being within the same block, it will be understood by those of ordinary skill in the art that the processor, computer, or memory may actually comprise multiple processors, computers, or memories that may or may not be stored within the same physical housing. For example, memory may be a hard drive or other storage media located in a housing different from that of computer **110**. Accordingly, references to a processor or computer will be understood to include references to a collection of processors or computers or memories that may or may not operate in parallel. Rather than using a single processor to perform the steps described herein, some of the components, such as steering components, acceleration and deceleration components, may each have their own processor that only performs calculations related to the component's specific function.

In various aspects described herein, the processor may be located remotely from the vehicle and communicate with the vehicle wirelessly. In other aspects, some of the processes described herein are executed on a processor disposed within the vehicle and others by a remote processor, including taking the steps necessary to execute a single maneuver.

Computer **110** may all of the components normally used in connection with a computer such as a central processing unit (CPU), memory (e.g., RAM and internal hard drives) storing data **134** and instructions such as a web browser, an electronic display **142** (e.g., a monitor having a screen, a small LCD touch-screen or any other electrical device that is operable to display information), user input **140** (e.g., a mouse, keyboard, touch screen and/or microphone), as well as various sensors (e.g., a video camera) for gathering explicit (e.g., a gesture) or implicit (e.g., "the person is asleep") information about the states and desires of a person.

In one example, computer **110** may be an autonomous driving computing system incorporated into vehicle **101**. FIG. **2** depicts an exemplary design of the interior of an autonomous vehicle. The autonomous vehicle may include all of the features of a non-autonomous vehicle, for example: a steering apparatus, such as steering wheel **210**; a navigation display apparatus, such as navigation display **215**; and a gear selector apparatus, such as gear shifter **220**. The vehicle may also have various user input devices, such as gear shifter **220**, touch screen **217**, or button inputs **219**, for activating or deactivating one or more autonomous driving modes and for enabling a driver or driver **290** to provide information, such as a navigation destination, to the autonomous driving computer **110**.

Vehicle **101** may include one or more additional displays. For example, the vehicle may include a display **225** for displaying information regarding the status of the autonomous vehicle or its computer. In another example, the vehicle may include a status indicating apparatus **138** (see FIG. **1**), such as status bar **230**, to indicate the current status of vehicle **101**. In the example of FIG. **2**, status bar **230** displays "D" and "2 mph" indicating that the vehicle is presently in drive mode and is moving at 2 miles per hour. In that regard, the vehicle may display text on an electronic display, illuminate portions of vehicle **101**, such as steering wheel **210**, or provide various other types of indications.

The autonomous driving computing system may capable of communicating with various components of the vehicle. For example, returning to FIG. **1**, computer **110** may be in communication with the vehicle's central processor **160** and may send and receive information from the various systems of vehicle **101**, for example the braking **180**, acceleration **182**, signaling **184**, and navigation **186** systems in order to control the movement, speed, etc. of vehicle **101**. In addition, when engaged, computer **110** may control some or all of these functions of vehicle **101** and thus be fully or merely partially autonomous. It will be understood that although various systems and computer **110** are shown within vehicle **101**, these elements may be external to vehicle **101** or physically separated by large distances.

The vehicle may also include a geographic position component **144** in communication with computer **110** for determining the geographic location of the device. For example, the position component may include a GPS receiver to determine the device's latitude, longitude and/or altitude position. Other location systems such as laser-based localization systems, inertial-aided GPS, or camera-based localization may also be used to identify the location of the vehicle. The location of the vehicle may include an absolute geographical location, such as latitude, longitude, and altitude as well as relative location information, such as location relative to other cars immediately around it which can often be determined with less noise that absolute geographical location.

The vehicle may also include other devices in communication with computer **110**, such as an accelerometer, gyroscope or another direction/speed detection device **146** to determine the direction and speed of the vehicle or changes thereto. By way of example only, acceleration device **146** may determine its pitch, yaw or roll (or changes thereto) relative to the direction of gravity or a plane perpendicular thereto. The device may also track increases or decreases in speed and the direction of such changes. The device's provision of location and orientation data as set forth herein may be provided automatically to the user, computer **110**, other computers and combinations of the foregoing.

The computer **110** may control the direction and speed of the vehicle by controlling various components. By way of example, if the vehicle is operating in a completely autonomous mode, computer **110** may cause the vehicle to accelerate (e.g., by increasing fuel or other energy provided to the engine), decelerate (e.g., by decreasing the fuel supplied to the engine or by applying brakes) and change direction (e.g., by turning the front two wheels).

The vehicle may also include one or more object detection components **148** for detecting objects external to the vehicle such as other vehicles, obstacles in the roadway, traffic signals, signs, trees, etc. The detection system may include lasers, sonar, radar, cameras or any other detection devices which record data which may be processed by computer **110**. For example, if the vehicle is a small driver vehicle, the car may include a laser mounted on the roof or other convenient location.

As shown in FIG. **3**, small driver vehicle **300** may include lasers **310** and **311**, mounted on the front and top of the vehicle, respectively. Laser **310** may have a range of 150 meters, a thirty degree vertical field of view, and a thirty degree horizontal field of view. Laser **311** may have a range of 50-80 meters, a thirty degree vertical field of view, and a 360 degree horizontal field of view. The lasers may provide the vehicle with range and intensity information which the computer may use to identify the location and distance of various objects. In one aspect, the lasers may measure the distance between the vehicle and the object surfaces facing the vehicle by spinning on its axis and changing its pitch.

The vehicle may also include various radar detection units, such as those used for adaptive cruise control systems. The radar detection units may be located on the front and back of the car as well as on either side of the front bumper. As shown in the example of FIG. **3**, vehicle **300** includes radar detection units **320-323** located on the side (only one side being shown), front and rear of the vehicle. Each of these radar detection units may have a range of 200 meters for an 18 degree field of view as well as a range of 60 meters for a 56 degree field of view.

In another example, a variety of cameras may be mounted on the vehicle. The cameras may be mounted at predetermined distances so that the parallax from the images of 2 or more cameras may be used to compute the distance to various objects. As shown in FIG. **3**, vehicle **300** may include 2 cameras **330-331** mounted under a windshield **340** near the rear view mirror (not shown). Camera **330** may include a range of 200 meters and a 30 degree horizontal field of view, while camera **331** may include a range of 100 meters and a 60 degree horizontal field of view.

The aforementioned sensors may allow the vehicle to evaluate and potentially respond to its environment in order to maximize safety for the driver, other drivers, as well as objects or people in the environment. It will be understood that the vehicle types, number and type of sensors, the sensor locations, the sensor fields of view, and the sensors' sensor fields are merely exemplary. Various other configurations may also be utilized.

In addition to the sensors described above, the computer may also use input from sensors typical non-autonomous vehicles. For example, these sensors may include tire pressure sensors, engine temperature sensors, brake heat sensors, break pad status sensors, tire tread sensors, fuel sensors, oil level and quality sensors, air quality sensors (for detecting temperature, humidity, or particulates in the air), etc.

Many of these sensors provide data that is processed by the computer in real-time, that is, the sensors may continuously update their output to reflect the environment being sensed at or over a range of time, and continuously or as-demanded provide that updated output to the computer so that the computer can determine whether the vehicle's then-current direction or speed should be modified in response to the sensed environment.

In addition to processing data provided by the various sensors, the computer may rely on environmental data that was obtained at a previous point in time and is expected to persist regardless of the vehicle's presence in the environment. For example, returning to FIG. **1**, data **134** may include detailed map information **136**, e.g., highly detailed maps identifying the shape and elevation of roadways, lane lines, intersections, crosswalks, speed limits, traffic signals, buildings, signs, real time traffic information, or other such objects and information. For example, the map information may include explicit speed limit information associated with various roadway segments. The speed limit data may be entered manually or scanned from previously taken images of a speed limit sign using, for example, optical-character recognition. The map information may include three-dimensional terrain maps incorporating one or more of objects listed above. For example, the vehicle may determine that another car is expected to turn based on real-time data (e.g., using its sensors to determine the current GPS position of another car) and other data (e.g., comparing the GPS position with previously-stored lane-specific map data to determine whether the other car is within a turn lane).

Again, although the map information is depicted herein as an image-based map, the map information need not be entirely image based (for example, raster). For example, the map information may include one or more roadgraphs or graph networks of information such as roads, lanes, intersections, and the connections between these features. Each feature may be stored as graph data and may be associated with information such as a geographic location and whether or not it is linked to other related features, for example, a stop sign may be linked to a road and an intersection, etc. In some examples, the associated data may include grid-based indices of a roadgraph to allow for efficient lookup of certain roadgraph features.

For example, map **400** of FIG. **4** is an exemplary pictorial representation of a portion of a roadgraph including a two lane road which passes under a highway **420** at overpass section **425**. The map includes features such as eastbound lane **412**, westbound lane **414**, and exit lane **416** of the road **410**. Similarly, highway **420** includes a median **422**, northbound lanes **426**, southbound lanes **424**, and shoulders **428**. Eastbound lane of the road **410** connects with highway **420** by way of exit lane **416**, entrance ramp **430**, and acceleration lane **440**. The map may also include additional roadway details such as double yellow lines **450** and lane lines **452** as well as signs (not shown) or other roadway features.

In some examples the map information may include zones. Each zone may comprise a geolocated area or point associated with particular rules. The zones may include places where driving may become complicated or challenging for humans and computers, such as merges, construction zones, or other obstacles. As described in more detail below, a zone's rules may require an autonomous vehicle to alert the driver that the vehicle is approaching an area where it may be challenging for the vehicle to drive autonomously. In one example, the vehicle may require a driver to take control of steering, acceleration, deceleration, etc. In another example, a zone's rules may require an autonomous vehicle to alert the driver, but rather than requiring the driver to take control, the vehicle may lower its speed and/or increase its following distance (between the autonomous vehicle and another vehicle).

For example, as shown in map **500** of FIG. **5**, the map information may include zone **510**. This zone includes acceleration lane **440** where merging into traffic may be difficult for an autonomous vehicle. Because of this difficulty, zone **510** may be associated with a rule which requires a driver to take control of steering, acceleration, and/or braking of the autonomous vehicle while within zone **510**.

In addition to the operations described above and illustrated in the figures, various operations will now be described. It should be understood that the following operations do not have to be performed in the precise order described below. Rather, various steps can be handled in a different order or simultaneously, and steps may also be added or omitted.

An autonomous vehicle may transport itself, a driver, passengers, and/or cargo between two locations by following a route. For example, a driver may input a destination and

activate an autonomous mode of the vehicle. In response, the vehicle's computer may calculate a route based on the roadgraph, its current location, and the destination. The route may include information such as where to turn, at what speeds to travel, where to look for traffic signals, where to stop for intersections or stop signs, etc. For example, as shown in map **600** of FIG. **6**, route **610** may require an autonomous vehicle to take the road **410** and exit onto highway **420**. This may require the vehicle to travel in the eastbound lane **412** of the road **410** to exit lane **416** to entrance ramp **430** to acceleration lane **440** and onto highway **420**. While not all routes may include zones, in the example of FIG. **6**, route **610** also requires the autonomous vehicle to pass through zone **510**.

As shown in map **700** of FIG. **7**, autonomous vehicle **300** travels along route **610**. As autonomous vehicle **300** approaches zone **510**, the autonomous vehicle's computer may identify the rules associated with zone **510**. As noted above, zone **510**'s rules may require that a driver take control of steering, acceleration and braking while the autonomous vehicle passes through zone **510**, for example, from point **710** to point **720** along route **610**.

The autonomous vehicle may notify a driver that the vehicle is approaching a zone with particular rules by providing visual or audible cues to the driver. The notifications may be based on a combination of time and distance to the zone. If the autonomous vehicle is moving at a reasonable speed, the notification may be based upon an estimated time to cross the remaining distance to the zone. For example, if vehicle **1** is moving at 25 miles per hour, the notification may be given when vehicle **1** is X distance from the zone. If vehicle **2** is moving at 50 miles per hour, the notification may be given when vehicle **2** is 2X distance from the zone. Thus, the time to the zone may be the same for both vehicles **1** and **2**. If the autonomous vehicle is moving at very slow speeds, for example in stop-and-go traffic, the notification may be based upon the distance to the zone.

For example, before reaching point **710**, autonomous vehicle **300**'s computer may present a warning to the driver, for example on display **225**, on status bar **230**, audibly, etc. indicating that the vehicle is approaching or within some distance of a zone which requires the driver to take control of the vehicle. For example, the vehicle may display a map similar to map **700** highlighting the zone and announce through a speaker "please take control of the vehicle while passing through the zone." The warnings may also include flashing lights, beeping, vibrating, etc.

In response to the warning, the driver may select to navigate around the zone, ignore the zone and rules, or simply take over control of one or more aspects of the autonomous vehicle. For example, the driver may request that the autonomous vehicle route itself around the zone so that the driver does not need to take control. The driver may, for example, speak his request or select an option using one or more inputs, such as a touch screen or button inputs **219**. The autonomous vehicle's computer may re-route itself and identify a new route which does not require the vehicle to pass through a zone.

In another example, the driver may elect to ignore the zone. In response, the vehicle, if it is able, may continue to drive itself through the zone. This may be helpful where there are no other vehicles, pedestrians, obstacles, etc. In this case, the vehicle may cease warning the driver, may continue to warn the driver that the vehicle is approaching a zone (until the vehicle reaches the zone), or the warning may change, for example, where the vehicle is within the zone. The new warning may be somewhat more serious, for example, warning that failure to take control may be dangerous in certain situations, increasing audible or tactile cues, flashing lights, etc.

In some examples, the rules may only require that the driver take control of the steering, acceleration and braking, or all of these features. For example, if the zone is a park or other location where pedestrians are typically walking, the vehicle may slow down dramatically and require the driver only to steer by turning the steering wheel **210**. In another example, if the zone is a merge onto a highway, the autonomous vehicle may steer itself to remain in the middle of the lane while the driver controls the acceleration and deceleration (gas and brake) to adjust the vehicle's speed based on merging traffic.

In yet another example, rather than following a particular route to a destination, a driver may instruct the autonomous vehicle to continue on a particular roadway until the driver resumes control or provides further instructions to the vehicle. For example, a driver may allow the vehicle's computer to steer the vehicle and control the vehicle's speed along the highway until the driver takes control of the steering wheel, acceleration, braking, etc. In this example, the computer may control the vehicle to follow the path of the roadway or the particular lane in which the vehicle currently is. If the vehicle is approaching a zone through which the vehicle would pass if it continued along the current path, the computer may notify the driver of the approaching zone. The computer may also identify the need to take control of some control feature (steering, braking, acceleration, etc.), and the computer may also take one or more of the actions described above. In response, as described above, the driver may take control of the control feature, ignore the warning, route the vehicle around the zone, etc.

However, merely approaching a zone may not be sufficient to initiate the warnings to a driver. For example, as shown in map **800** of FIG. **8**, autonomous vehicle **300**-A is traveling along route **810** approaching overpass section **425** of highway **420** in eastbound lane **412** of the road **410**. Although the vehicle is approaching zone **510**, the autonomous vehicle may not actually provide any warnings to the driver as the vehicle is not actually traveling through zone **510**, but below the zone. Similarly, autonomous vehicle **300**-B is traveling along route **820** in a northbound lane **426** of highway **420** passing zone **510**. Again, although vehicle **300**-B may come very close to zone **510**, the vehicle may not provide its driver with a warning as the vehicle may not actually travel through zone **510**, but next to the zone.

Flow diagram **900** of FIGS. **9**A-**9**C provides an exemplary overview of the process described above. As shown in block **902** of FIG. **9**A, an autonomous vehicle's computer may identify a destination location and a current location of the vehicle. For example, a driver may enter a destination location into a navigation device of the vehicle. The current location of the vehicle may be determined based on data received from one or more geographic location devices. At block **904**, the computer accesses map information including one or more zones. Each zone is associated with a rule which requires a driver to take control of a control aspect of the vehicle. For example, a rule may require a driver to control the steering, acceleration, and/or braking of the vehicle while the vehicle is in the zone. At block **906**, the computer generates a route from the current location to the destination location based on the map information, where the route requires the vehicle to pass through at least one zone. As noted above, the route need not include zones.

The computer then controls the vehicle to the destination along the route at block **908**. At block **910**, the computer determines whether the vehicle is approaching the at least one

zone. For example, based on the current speed of the vehicle, the computer may determine whether the vehicle is within a particular distance from or an estimated time to reach the zone. If not, the computer continues to control the vehicle to the destination at block **908**. Returning to block **910**, if the computer determines that the vehicle is approaching the at least one zone, the computer identifies the rule and the control aspect, associated with at least one zone at block **912**.

The computer then notifies the driver of the need to control the identified control aspect through the at least one zone at block **914**. In one example, the computer receives information indicating that the driver has taken control of the identified control aspect at block **916**. The computer waits until the vehicle has left the at least one zone and the driver has relinquished control of the identified control aspect at block **918**. The computer then continues to control the vehicle along the route towards the destination at block **908**.

In another example, the driver may decide to instruct the computer to avoid the at least one zone. As shown in block **920** of FIG. **9**B, the computer receives instructions from the driver to avoid the zone. In response, the computer generates a new route to the destination which does not pass through the at least one zone at block **922**. The computer then continues to control the vehicle along the new route towards the destination at block **908**.

In yet another example, after notifying the driver of the approaching zone, the computer may receive no input as shown in block **924** of FIG. **9**C. The computer may continue to notify the driver of the need to control the identified control aspect through the at least one zone. Once the vehicle reaches the at least one zone, the computer may control the vehicle through the at least one zone at block **926**. The computer then continues to control the vehicle along the route towards the destination at block **908**.

As noted above, the zones may be pre-identified in the roadgraph or may be set on demand by a driver. For example, a driver who notices a temporary construction or roadblock may tag the location as one at which vehicles should not drive autonomously. In that regard, the driver may take control of the vehicle and at the same time, generate a zone rule for the location. The new zone may begin where the driver has taken control of the autonomous vehicle and end where the driver has relinquished control to the computer. In some example, the new zones may be temporarily stored by the vehicle. The length of time may be based on the reason for the zone. For example, some construction projects may take only a day while others may take much longer. In this example, the driver may use the inputs to identify how long the computer is to keep the zone.

For example, as shown in map **1000** of FIG. **10**, autonomous vehicle **300** is driving along roadway **1010**. The roadway includes features such as southbound lane **1002**, northbound lane **1004**, double yellow line **1006**, lane lines **1008**, etc. In this example vehicle **300** is following route **1020** along northbound lane **1004**. As vehicle **300** approaches point **1050**, the driver may identify a temporary construction situation. In this example, cones **1030** have been set up to route vehicles around the construction vehicles **1040**. Vehicle **300** may identify all of these objects, but its computer may determine that it is unable to route itself through the cones as they would require the vehicle to pass into the southbound lane. In this example, the driver may take control of the vehicle at point **1050** and relinquish control of the vehicle at point **1060** when the vehicle has cleared the temporary construction situation. In response, the vehicle may generate a new zone in the northbound lane of roadway **1000** between points **1050** and **1060** where the driver took control of the vehicle.

Once the new zone has been generated, the new zone may also be broadcast to other nearby autonomous vehicles. For example, the autonomous vehicle may use a radio link or other network such that other vehicles may be able to observe the same rule (take control of the steering, acceleration, and/or braking) at the new zone or notify the other vehicles' drivers that another driver felt the location was unsafe for autonomous driving. Returning to FIG. **10**, vehicle **300** may transmit to information other vehicles identifying a new zone in northbound lane of roadway **1000** between points **1050** and **1060** where the driver took control of the vehicle. As another vehicle, following a route through point **1050** towards point **1060** approach point **1050** the other vehicle may display notifications to its own driver. These notifications may be similar to the notification described above, but may also indicate that the zone was one recently identified by another driver.

The autonomous vehicle may also allow a driver to navigate around zones or simply ignore them in advance. For example, the vehicle's default condition may be to route the vehicle through zones if it is the fastest way to the destination. The driver may select to avoid zones while entering a destination or may select to turn off the zone feature such that no warning is given and the vehicle drives through the zones anyway. The driver may also select to ignore the zones permanently, ignore only those stored in the vehicle's map, or ignore zones identified by other drivers and broadcast by the other drivers' autonomous vehicles.

As these and other variations and combinations of the features discussed above can be utilized without departing from the subject matter as defined by the claims, the foregoing description of exemplary embodiments should be taken by way of illustration rather than by way of limitation of the subject matter as defined by the claims. It will also be understood that the provision of the examples described herein (as well as clauses phrased as "such as," "e.g.", "including" and the like) should not be interpreted as limiting the claimed subject matter to the specific examples; rather, the examples are intended to illustrate only some of many possible aspects.

The invention claimed is:

1. A method for maneuvering a vehicle, the method comprising:

accessing, by one or more processors, map information including a geographic area associated with a rule that indicates a driver to take control of at least one control aspect of the vehicle;

maneuvering, by the one or more processors, the vehicle in an autonomous driving mode by controlling a first control aspect of the vehicle and a second control aspect of the vehicle without continuous input from the driver, wherein the first and second control aspects are selected from the group consisting of acceleration, deceleration, and steering;

determining, by the one or more processors, when the vehicle is within a predetermined distance from the geographic area;

when the vehicle is determined to be within a predetermined distance from the geographic area, identifying, by the one or more processors, the at least one control aspect using the map information;

generating, by the one or more processors, a notification indicating of the need to control the identified at least one control aspect through the geographic area;

receiving, by the one or more processors, input indicating that the driver is controlling the first control aspect; and

in response to receiving the input and while the driver is controlling the first control aspect, continuing, by the

one or more processors, to control the second control aspect through the geographic area.

2. The method of claim 1, wherein the first control aspect is the steering control and the second control aspect is the acceleration control.

3. The method of claim 1, wherein the first control aspect is the acceleration control and the second control aspect is the steering control.

4. The method of claim 1, wherein the first control aspect is the deceleration control and the second control aspect is the steering control.

5. The method of claim 1, further comprising:

determining, by the one or more processors, when the vehicle has passed through the geographic area and the driver has relinquished control of the first control aspect; and

when the vehicle is determined to have passed through the geographic area and the driver is determined to have relinquished control of the first control aspect, maneuvering the vehicle, by the one or more processors, by controlling the first control aspect and the second control aspect.

6. The method of claim 1, further comprising:

after generating the notification, determining that the driver has not taken control of the first control aspect; and

when the driver is determine to have not taken control of the first control aspect, escalating an aspect of the notification.

7. The method of claim 1, further comprising determining, by the one or more processors, the predetermined distance based on a current speed of the vehicle.

8. A system for maneuvering a vehicle, the comprising:

memory storing map information including a geographic area associated with a rule that indicates a driver to take control of at least one control aspect of the vehicle;

one or more processors configured to:

access the memory; maneuver the vehicle in an autonomous driving mode by controlling a first control aspect of the vehicle and a second control aspect of the vehicle without continuous input from the driver, wherein the first and second control aspects are selected from the group consisting of acceleration, deceleration, and steering;

determine when the vehicle is within a predetermined distance from the geographic area;

when the vehicle is determined to be within a predetermined distance from the geographic area, identify the at least one control aspect using the map information;

generate a notification indicating of the need to control the identified at least one control aspect through the geographic area;

receive input indicating that the driver is controlling the first control aspect; and

in response to receiving the input and while the driver is controlling the first control aspect, continue to control the second control aspect through the geographic area.

9. The system of claim 8, wherein the first control aspect is the steering control and the second control aspect is the acceleration control.

10. The system of claim 8, wherein the first control aspect is the acceleration control and the second control aspect is the steering control.

11. The system of claim 8, wherein the first control aspect is the deceleration control and the second control aspect is the steering control.

12. The system of claim 8, wherein the one or more processors are further configured to:

determine when the vehicle has passed through the geographic area and the driver has relinquished control of the first control aspect; and

when the vehicle is determined to have passed through the geographic area and the driver is determined to have relinquished control of the first control aspect, maneuver the vehicle by controlling the first control aspect and the second control aspect.

13. The system of claim 8, wherein the one or more processors are further configured to:

after generating the notification, determine that the driver has not taken control of the first control aspect; and

when the driver is determine to have not taken control of the first control aspect, escalate an aspect of the notification.

14. The system of claim 8, wherein the one or more processors are further configured to determine the predetermined distance based on a current speed of the vehicle.

15. A tangible, non-transitory, computer-readable storage medium on which computer readable instructions of a program are stored, the instructions, when executed by a processor, cause the processor to perform a method of maneuvering a vehicle, the method comprising:

accessing map information including a geographic area associated with a rule that indicates a driver to take control of at least one control aspect of the vehicle;

maneuvering the vehicle in an autonomous driving mode by controlling a first control aspect of the vehicle and a second control aspect of the vehicle without continuous input from the driver, wherein the first and second control aspects are selected from the group consisting of acceleration, deceleration, and steering;

determining when the vehicle is within a predetermined distance from the geographic area;

when the vehicle is determined to be within a predetermined distance from the geographic area, identifying the at least one control aspect using the map information;

generating a notification indicating of the need to control the identified at least one control aspect through the geographic area;

receiving input indicating that the driver is controlling the first control aspect; and

in response to receiving the input and while the driver is controlling the first control aspect, continuing to control the second control aspect through the geographic area.

16. The medium of claim 15, wherein the first control aspect is the steering control and the second control aspect is the acceleration control.

17. The medium of claim 15, wherein the first control aspect is the acceleration control and the second control aspect is the steering control.

18. The medium of claim 15, wherein the first control aspect is the deceleration control and the second control aspect is the steering control.

19. The medium of claim 15, wherein the method further comprises:

after generating the notification, determining that the driver has not taken control of the first control aspect; and

when the driver is determine to have not taken control of the first control aspect, escalating an aspect of the notification.

20. The medium of claim 15, wherein the method further comprises determining, by the one or more processors, the predetermined distance based on a current speed of the vehicle.

* * * * *

UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

PATENT NO.	: 9,268,332 B2
APPLICATION NO.	: 14/324470
DATED	: February 23, 2016
INVENTOR(S)	: Michael Steven Montemerlo, Dmitri A. Dolgov and Christopher Paul Urmson

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

On the Title Page (*) Notice: "Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days." should read --This patent is subject to a terminal disclaimer, Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.--

Signed and Sealed this
Third Day of May, 2016

Michelle K. Lee

Michelle K. Lee
Director of the United States Patent and Trademark Office